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Phylogeny and cultural history in ontogeny

Abstract

The purpose of this paper is to defend the contention that human culture is constitutive of human psychological processes. Several kinds of evidence are presented in support of this proposition: phenomena associated with the stabilization of images on the retina and their selective disappearance and reappearance when varying degrees of destabilization are introduced; the non-linearity of cultural/cognitive time which acts as a transformative mechanism uniting the material and ideal aspects of culture; data on the operation of culture as a non-linear source of structuration in human ontogeny, and finally, data on the ways in which cultural practices influence the functioning of the brain.

1. Introduction

It is my belief that contemporary study of the role of culture in human development is hampered by the continued failure of behavioral scientists to take seriously the implications of the co-evolution of phylogenetic and cultural-historical change in shaping processes of developmental change during ontogeny. The wide acceptance by psychologists and neuroscientists of the central importance of biological evolution in shaping human characteristics has, I believe, created a situation in which the role of culture in the process of creating human natures is considered so secondary that it can be easily dismissed. Culture, in this view, is little more than a patina of noise obscuring an otherwise clear picture of the mechanisms of human thought, feeling, and action. This view was expressed colourfully many years ago by Gesell (1945, p. 358) when he declared that:

> *‘‘Neither physical nor cultural environment contains any architectonic arrangements like the mechanisms of growth. Culture accumulates, it does not grow. The glove goes on the hand; the hand determines the glove.”*

A quite different view was offered by the anthropologist, Geertz, who, while not denying the centrality of biological evolution to the emergence of Homo sapiens, made the case for the critical importance of culture in that evolutionary process in equally colorful language:

> *"Man's nervous system does not merely enable him to acquire culture, it positively demands that he do so if it is going to function at all. Rather than culture acting only to supplement, develop, and extend organically based capacities logically and geneticallyprior to it, it would seem to be ingredient to those capacities themselves. A culture-less human being would probably turn out to be not an intrinsically talented, though unfulfilled ape, but a wholly mindless and consequently unworkable monstrosity (1973, p. 67–68). "*

Of course, Geertz was arguing from scanty data, but contemporary studies of hominization in which culture has been shown to be ''ingredient to the process" combined with experimental evidence demonstrating changes in brain structure and functioning associated with culturally organized variations in experience have been kinder to Geertz than Gesell. Thus, for example, evolutionary psychologist Plotkin (2001) has recently concluded that ''Human evolution and cultural evolution are two-way streets of causal interactions" (p. 93). Based upon contemporary neuroscientific evidence, Quartz and Sejnowski, declare that culture "contains part of the developmental program that works with genes to build the brain that underlies who you are" (2002, p. 58). Donald (2001) makes the same point in slightly different terms: "Culture actually configures the complex symbolic systems needed to support it by engineering the functional capture of the brain for epigenesis" (p. 23). More recently Li (2006) has coined the term ''bio-cultural co-constructivism" to characterize this view.

In light of my own predilections and the increasing availability of relevant date, my goal in the remainder of this paper is to make the case for the inter-twining of phylogeny and culture in human mental life implied by these latter authors. In doing so, I will draw upon a variety of data, some of which they did not consider.

2. Culture: what are we talking about?

The polysemy of the term culture, even within the discipline of anthropology for which it is foundational, is legendary. So, recognizing that there is unlikely to be close agreement, the best I can do is to mark distinctions along a spectrum of definitions that is important to keep in mind in the current discussion.

Perhaps the most ubiquitous definition of "culture" was offered by the anthropologists, Kroeber and Kluckhohn after surveying a great many definitions in the then-extant literature:

> *"Culture consists of patterns, explicit and implicit, of and for behavior acquired and transmitted by symbols, constituting the distinctive achievements of human groups, including their embodiment in artifacts; the essential core of culture consists of traditional (i.e., historically derived and selected) ideas and especially their attached values; cultural systems may on the one hand be considered as products of action, on the other as conditioning elements of further action (1952, p. 181)."*

This definition is useful in the present context because it indexes a critical distinction that to some degree lurks in all other definitions, but often in hidden form, and it needs to be brought into clear view. Culture, in this definition, is mixture of elements – both material things ''out there in the world," and mental entities (ideas and values), that are presumably ''in here," in the human mind. Moreover the form of those mental entities is specified as symbols, by which is usually meant a representational token for a concept or quantity; i.e. an idea, object, concept, quality, etc. Just how the material and ideal/symbolic aspects of culture are related to each other and the relation of culture to human cognition remains a topic of deep dispute (see D'Andrade, 2001).

By contrast, recent interest in the possibility that many primate groups appear to ''have culture" has resulted in an agreement among primatologists that the core notion of culture is ''group-specific behavior that is acquired, at least in part, through social influences" (McGrew, 1998, p. 305) or ''behavioral conformity spread or maintained by non-genetic means" through processes of social learning (Whiten, 2000, p. 284). By this minimalist definition, culture is not specific to human beings and there is no commitment to a central role for symbols in the ''behavioral conformity" observed. Rather, in several prominent cases (e.g., using rocks to break open nuts) the materiality of elements of the behavior involved is most obvious. For the present, it is sufficient to note that even those who argue for the presence of culture among non-human primates generally agree that there is more to human culture than non-genetically transmitted behavioral patterns, just as there is more to human cognition than is found in non-human primates. However, disagreements about precisely what this "more" is and what the differences in the nature of culture among species tell us about the role of culture in human phylogeny and current cognitive development have produced a massive and contentious literature (Byrne et al., 2004).

In the materials to follow,I hope to contribute a little to understanding this complex relationship.

The paper proceeds as follows. First, I summarize evidence from experiments on very short term changes in visual perception under extraordinary circumstances that appears to require us to acknowledge the role of both culturally organized experience and phylogenetically ‘‘hard wiring” in our ordinary perception of the world. At the same time, these microgenetic data emphasize that phylogeny and cultural–historical experience, while necessary to normal perception are not sufficient. Second,I make the case that in an important sense, cultural–historical time is non-linear with respect to the ways in which it enters into the process of human thought quite generally and human ontogeny in particular. This conclusion is buttressed by a selection of empirical examples from children of different ages living in different cultural circumstances. Each of these cases underlines the complementarity of the material and symbolic aspects of culture and its mediation of human experience. Third, I review recent evidence that normal cognitive development requires us to assume that phylogeny provides children with “skeletal”, “domain specific” capacities that must be “fleshed out” through participation in cultural practices for them to develop normally during ontogeny. Fourth, I point to a small, but rapidly expanding corpus of research indicating that involvement in practices which are of cultural–historical origin may modify both the morphology and on-line functioning of the brain. With these data in hand I return briefly to underline my basic contention that phylogeny and cultural history reciprocally constitute each other in the process of human ontogeny.

3. Three parts of an image: a productive metaphor for the relation of phylogeny and culture in cognition

A provocative way to think about phylogeny–culture– cognition relations among humans is to consider the com-bination of processes that appears to be necessary for an adult human to experience a visual image of the world (the same processes presumably apply to images in other sensory modalities but the relevant data are lacking). Among other things, the concept of an image shares some of the ambiguity found in our discussion of the concept of culture. In English, an image is clearly a noun and it can be interpreted either as a mental or a material object (I can close my eyes and create an image of a chair or I can look at a photographic ‘‘image of a chair”). But this ‘‘thingness” of images masks the fact that for human beings to experience an image, it requires some kind of process. (Not coincidentally, the term, culture, in its early meanings in English also designated a process—the process of making things grows). Moreover, a good deal has been known for some time about this process with respect to visual images(Pritchard, 1971; Inhoff and Topolski, 1994).

Briefly, the facts are as follows: our eyes are in constant motion, not only as a result of voluntary movements of the eyes and the head, but owing to involuntary saccadic eye movements of 20–200 ms in duration (and even briefer ‘‘microsaccades”). Consequently, the eyes move with respect to a stationary object even if maximal effort is to made to stare at the object without moving. When visual images are stabilized on the retina using a special apparatus that moves in perfect coordination with the retina, the visual field goes grey, but it does so slowly and the images break up before they disappears. If there is slight slippage, fragments of the image reappear. However, the full image reappears only when there is free play of the image across the retina. The physiological mechanism for the total fading of the image is unproblematic: the cells of the retina respond to changes in luminance so they gradually loose responsivity when luminance is invariant. However, this unproblematic fact has some interesting implications. Most immediately, it means that discoordination with the world is constitutive of our perception of it. And it raises the question of what goes on between interval of total fixation on an object when information is maximally transmitted and maximal discoordination when no information reaches the eye from the object?

In seeking to answer this question, some additional facts are important to keep in mind. First, it appears that no useful visual informationis obtained during the fast, saccadic, eye movement; instead, all the effective information is obtained during the pauses between movements when the eye is fixated on the target (Matin et al., 1972). Second, because there is a (brief) time interval during which, so to speak, the eye looks away from (discoordinates with respect to) the object of interest and the time it fixes upon it again, literally speaking, there must be a discontinuity in our perception of the world. However, we experience our perception of the world as continuous. Because of the passage of time and the fact that, in ordinary circumstances movement, however slight, occurs between fixations, when we re-fix upon the target object we see it from a different angle against a different background. Yet we have no consciousness of discrepancy.

Second, the fragments into which different kinds of visual images break up and disappear and then reappear when there is slippage of the apparatus coordinating the visual image and the retina depend upon the kind of stimulus that is presented. Two different classes of images are of central importance to the following discussion (see Fig. 1).

The HB and the female profile share certain characteristics such as the sharp changes of luminance at the borders between black and white. However, they differ in that the shape of the human head has been a part of the experience of Homo

sapiens over the entire course of its history, while the shape of the monogram is a recent, cultural, convention associated with alphabetic literacy.

The common visual mechanisms relating to points of high contrast shared by the two kinds of stimuli are evident in research with newborn infants. Within days of birth, if not at birth, infants are sensitive to the sharp changes in luminance as reflected in their eye movements (Bronson, 1997). As shown in Fig. 2, newborns fixate on the apex of the figure where the luminance gradients are most pronounced.

Fig. 1. The shapes into which the profile of a female head and the monogram, HB disintegrate when they are fixed with respect to the movement of the retina (adapted from Pritchard, 1971).

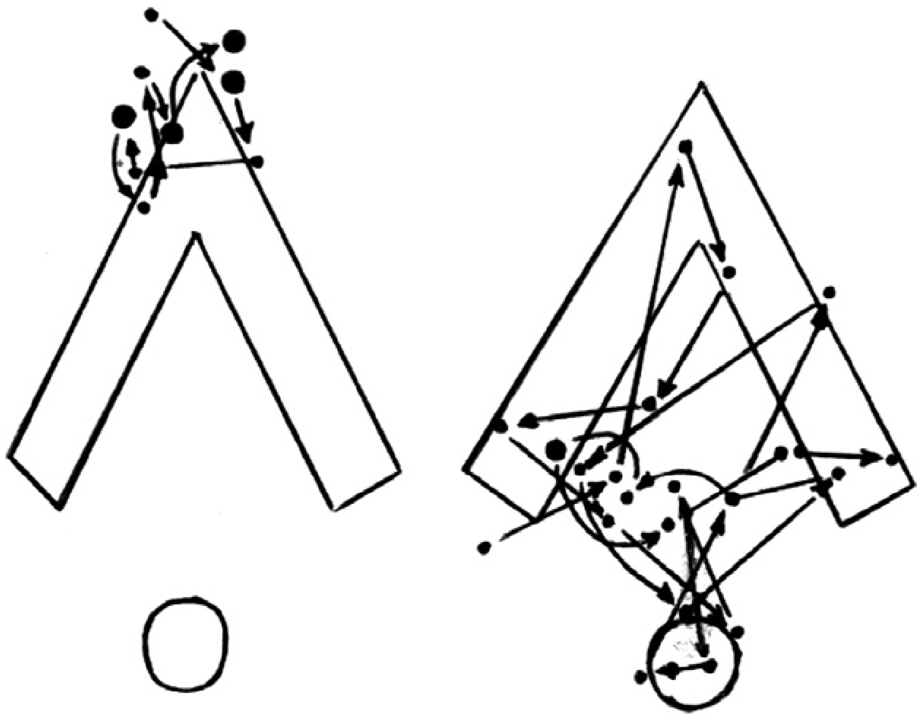

Fig.2. Changes in infant fixations on a triangular figure between 2 weeks and 12 weeks of age. The round circle between the two lines of the figure

indicated the location of the camera that recorded direction of infant gaze. Note that at 2 weeks the infant fixates almost entirely on the point of highest contrast (adapted from Bronson, 1991).

The profile and the monogram represent two distinctly different kinds of stimuli with respect to their origins. In particular, the face (except for the particular shape of the hairdo and the ribbon) is a kind of stimulus that all human beings experience from birth and are an essential part of their species makeup while a monogram made of two alphabetic characters is quintessentially a cultural object. By two days of age, infants are able to recognize their mother's faces, but they do so by detecting the distinctive features of her hairline, the point of greatest luminance contrast (Pascalis et al., 1995). It seems safe to conclude that images of facial profiles, such as that at the top of Fig. 1 are heavily influenced by phylogenetically constrained mechanisms.

By contrast, the fact that the fragments into which the HB monogram breaks up are all letters of the alphabet or written numbers cannot be attributed to phylogenetic history except in so far as luminance contrast is involved. Rather, each of the fragments is a meaningful (to literate persons) cultural unit. The subjects in these experiments have coordinated their actions through such artificially constructed graphic signs millions of times, achieving a very high level of automaticity. Following Hebb (1949), Pritchard suggests that as a result of such massive experience using graphic symbols they have formed cell assemblies, a kind of cortical "firmware" which facilitates maintenance and activation of their internal organization.

Following the logic of this line of research on what might be termed "the components of the visual image" we can conclude that one component is highly specified by factors arising from human beings' phylogenetic history and one part from the individual's culturally organized experience, which itself is the residue of the cultural history of the individual's social group. However, these two sources of experience are not sufficient to provide a coherent image of the object before one's eyes. Rather, it requires a ''third component," the active reconciliation or filling-in by active humans seeking to make sense of their experience for an integrated, veridical image of the world to arise and be maintained.

In addition to its value as a reminder of the tripartite nature of human conscious experience, the stabilized image experiment is valuable in underling the fact that the causal relations between the brain and culture are bi-directional and that neither constituent of psychological processes is sufficient; the active resolving activity of the human being striving to make sense of the world is a necessary component of normal consciousness as well.

4. On the non-linearity of cultural time

A feature of phylogeny–culture–ontogeny relationships that is not clearly evident in experiments on stabilized images is that different kinds of temporality that characterizes each of the components. Of course, it is to be taken for granted that phylogenetic history is of enormously greater duration, and in this sense, provides a far greater influence in the organization of psychological processes than cultural–historical or ontogenetic history (although we must also keep in mind that fact that for millions of years cultural-history has been intertwined with the phylogenetic organization of the brain).

Rather than focus on issues of phylogeny–culture relations in the process of hominization (see, Cole, 2006 for a review of this literature) I wish here to emphasize a feature of culture–ontogeny relations that directs our attention to the relation between the material and symbolic aspects of culture and that derives from what I refer to here as the ‘‘non-linearity of cultural time.” This non-linearity, I believe, is central to the ways in which the cultural organization of experience provides constraints that underpin the process by which culturally organized experience in ontogeny comes to change brain morphology and function.

4.1. Causation “from the future”: prolepsis

The most convincing illustration of what I mean by the non-linearity of cultural time with respect to human ontogeny is visible in the interactions that take place at the birth of a child. In this first encounter between generations parents make visible how the cultural past greets the newborn as its cultural future; the palpable constraints in place in adulthood are transformed into palpable constraints at birth and “future structure from the past” is transformed into constraints on the process of organism–environment interaction at birth. The name of the cultural mechanism that brings “the end into the beginning” is prolepsis, meaning “the representation of a future act or development as being presently existing” (Webster’s Dictionary).

This illustration comes from transcripts collected by the British pediatrician, Mac Farlane (1977) who tape recorded the conversations that took place between parents at their children’s birth. He found that the parents almost immediately start to talk about and to the child. Their comments arise in part from phylogenetically determined features (the anatomical differences between males and females) and in part from cultural features they have encountered in their own lives (including what they know to be typical of boys and girls). Typical comments include ‘‘I shall be worried to death when she’s eighteen” or “It can’t play rugby” (said of girls).

Putting aside our negative response to the sexism in these remarks, we see that the adults interpret the phylogenetic–biological characteristics of the child in terms of

their own past (cultural) experience. In the experience of English men and women living in the mid-20th century, it could be considered "common knowledge" that girls do not play rugby and that when they enter adolescence they will be the object of boys' sexual attention, putting them at various kinds of risk. Using this information derived from their cultural past and assuming cultural continuity (e.g., that the world will be very much for their daughter as it has been for them) parents project a probable future for the child.

This process is depicted in Fig. 3. The horizontal lines represent the different "genetic domains" or "streams of history" that are simultaneously operative at the moment of birth, which is indicated by the vertical line. The figure should be read using the numbers associated with each curved arrow: by following the arrows from the mother→ (remembered) cultural past of the mother→ (imagined) cultural future of the baby→ present adult treatment of the baby.

Two features of this system of transformations are essential to understand the contribution of culture in constituting development. First, and most obviously, we see an example of prolepsis. The parents represent and enact the future in the present. Secondly, if less obviously, the parents' (purely ideal) recall of their past and imagination of their child's future, becomes a fundamental materialized constraint on the child's life experiences in the present. This rather abstract, non-linear process of transformation is what gives rise to the well-known phenomenon that even adults totally ignorant of the real gender of a newborn will treat the baby quite differently depending upon its symbolic/cultural "gender". Adults literally create different material forms of interaction based on conceptions of the world provided by their cultural experience. For example, they bounce "boy" infants (those wearing blue diapers) and attribute "manly" virtues to them while they treat "girl" infants (those wearing pink diapers) in a gentle manner and attribute beauty and sweet temperaments to them (Rubin et al., 1974). (The assumption of cultural stability, of course, is wrong whenever there are conditions of cultural change following the birth of the child. The invention of new ways to exploit energy or new media of representation, or simple changes in custom, may sufficiently disrupt the existing cultural order to be a source of significant developmental discontinuity. As but a single example, in the 1950s American parents who assumed that their daughter would not be a soccer player at the age of 16 would have been correct, but in 1990 many American girls play soccer.)

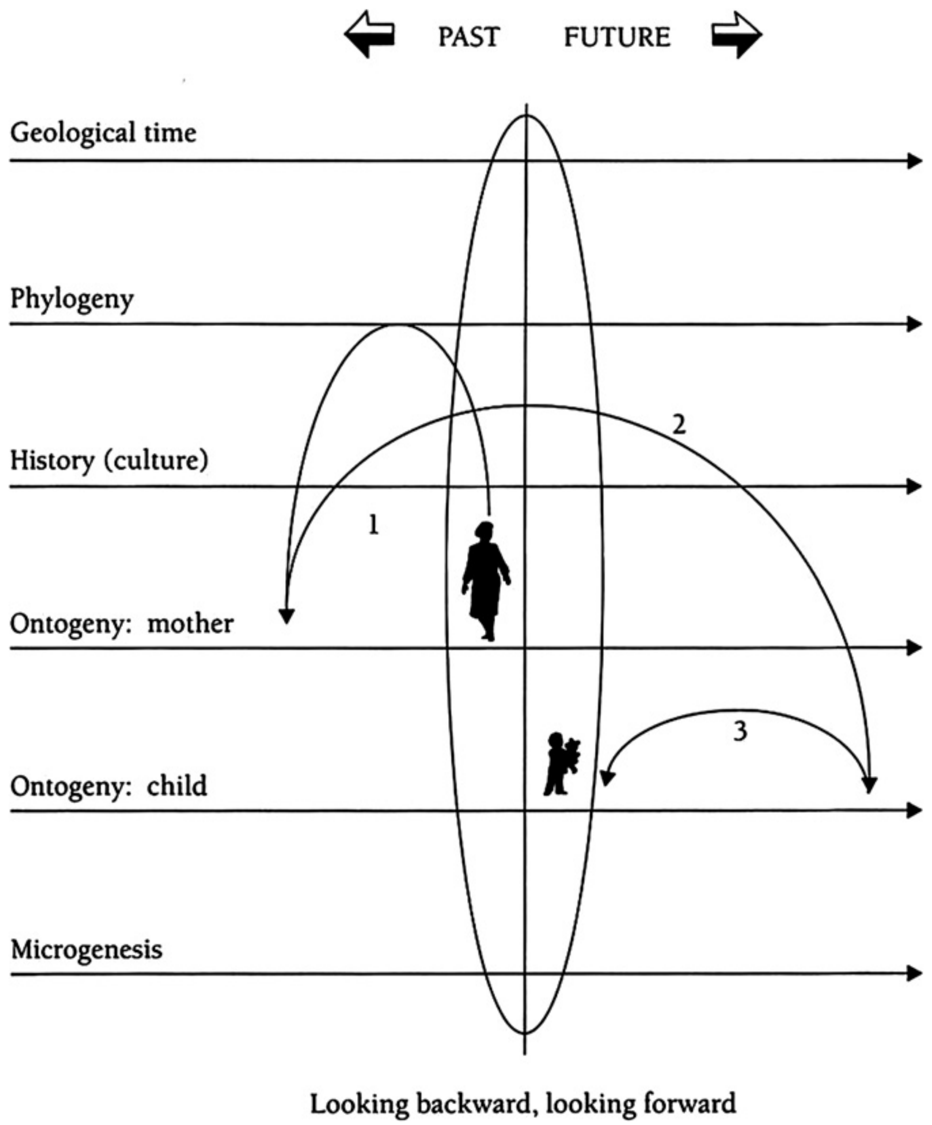

Fig. 3. The horizontal lines represent time scales corresponding to the history of the physical universe, the history of life on earth (phylogeny), the history of human beings on earth (cultural-historical time), the life of the individual (ontogeny), and the history of moment-to-moment lived experience (microgenesis). The vertical ellipse represents the event of a child's birth. The distribution of cognition in time is traced sequentially into (1) the mother's memory of her past, (2) the mother's imagination of the future of the child, and (3) the mother's subsequent behavior. In this sequence, the ideal aspect of culture is transformed into its material form as the mother and other adults structure the child's experience to be consistent with what they imagine to be the child's future identity.

This example also motivates the special emphasis placed on the social origins of higher psychological functions by cultural–historical psychologists (Cole, 1988; Rogoff, 2003; Valsiner, 1988; Vygotsky, 1978; Wertsch, 1985). Humans are social in a sense that is different from the sociability of other species. Only a culture-using human being can "reach into" the cultural past, project it into the future, and then

“carry” that conceptual future “back” into the present to create the socio-cultural environment of the newcomer.

I believe the process illustrated by Mac Farlane to be universal but I know of no recordings equivalent to Mac Farlane’s from other cultures. However, an interesting account of birthing among the Zinacanteco of South-central Mexico appears to show the same processes at work. In their summary of developmental research among the Zinacanteco, Greenfield et al. (1989) report a man’s account of his son’s birth at which the son was given three chilies to hold so that it would ... know to buy chili when it grew up. It was given a billhood, a digging stick, an axe, and a [strip of] palm so that it would learn to weave palm (p. 177).

Baby girls are given an equivalent set of objects associated with adult female status. The future orientation of differential treatment of the babies is not only present in ritual; it is coded in the Zinacantecan saying, “For in the newborn baby is the future of our world”.

5. Prolepsis as a ubiquitous feature of ontogenetic experience

To give some flavor of the ways in which the proleptic cultural organization of experience present at birth continues to provide specific patterns of culturally mediated experience that shape environmental influences on children’s experience I will give three examples from somewhat later periods of development, both of which involve comparisons of Japanese and American cultural practices.

5.1. The future in the present: the primacy of object and person orientation in infancy

Bornstein et al. (1990) studied interactions between American and Japanese mothers with their 5-month-old offspring. The focus of this work was the way that mothers living in New York and in Tokyo respond to their infants’ orientations to events in the environment or to the mothers themselves. Using a variety of measures of infant behaviors (level of activity, the rate at which they habituate to the sight of their mothers’ faces or objects in the environment, the level of vocalization of various kinds), Bornstein and his colleagues established the fact that 5-month-old infants in the two cultures behaved in similar manners and in this important sense, provided similar starting points for their mothers’ responses to them. Of particular importance in light of maternal behaviors, infants from the two societies displayed equal levels of orientation to their mothers and to physical objects in the environment.

Despite the fact that these infants represented equivalent stimuli in the objective sense provided by the researchers’ behavioral measurements, there was a

distinctive difference in the way that the mothers responded to their infants. American mothers were more responsive when their children oriented to physical objects in the environment; Japanese mothers were more responsive when their infants oriented to them. Moreover, the mothers made overt attempts to change the locus of their infants' orientation when it did not fit their preference; American mothers diverted children's attention from themselves to objects, whereas Japanese mothers showed the opposite pattern.

Once again we see a pervasive feature of cultural influences on development. Japanese maternal behavior is part of a system that highly values a strong dependence of the child on the mother whereas American maternal behavior is part of a system that values independence. These different value orientations make little difference to the welfare of the children at 5 months of age; both forms of interaction are caring and supportive. But they are part of a system of constraints on the children that do make a difference as the child grows older. Bornstein and his colleagues note that as toddlers, Japanese and American children do not differ in their global language and play skills. But they do differ in the kinds of language and the kinds of play, they are best at in ways that correspond to the differences evident in their mothers' behaviors at the age of 5 months. The Japanese pattern of promoting interpersonal over object orientations in early mother–child interactions is also reported for a variety of sub-Saharan African societies (Mohanty and Perregaux, 1997).

5.2. The future in the present in early childhood

Three to four year old children provide another clear illustration of how adults bring the future into the present in shaping children's experiences and future development. Tobin et al. (1989) conducted a comparative study of pre-school socialization in Hawaii, Japan, and China. They recorded classroom interactions that they then showed to teachers and other audiences in all three countries, to evoke their interpretations and basic cultural schemata relevant to the preschool child. Only the Japanese and American data are discussed here.

When Tobin and his colleagues videotaped a day in the life of a Japanese preschool, young Hiroki was acting up. He greeted the visitors by exposing his penis and waving it at them. He initiated fights, disrupted other children's games, and made obscene comments. When American preschool teachers observed the videotape they disapproved of Hiroki's behavior, his teacher's handling of it, and many aspects of life in the Japanese classroom in general. His teacher and other Japanese observers had a quite different interpretation. Starting first with the overall ambience of the classroom, Americans were scandalized by the fact that there were 30 preschoolers and only one teacher in the classroom. How could this be in an

affluent country like Japan? They could not understand why Hiroki was not isolated as punishment.

The Japanese had a very different interpretation. First, while teachers acknowledged that it would be very pleasant for them to have a smaller classroom, they believed it would be bad for the children, who “need to have the experience of being in a large group in order to learn to relate to lots of children in lots of kinds of situations” (Tobin et al., 1989, p. 37). When asked about their ideal notion of class size, the Japanese teachers generally named 15 or more students per teacher in contrast with the 4–8 preferred by American preschool teachers. When Japanese preschool teachers observed a tape of an American preschool they worried for the children. “A class that size seems kind of sad and under-populated”, one remarked. Another added, ‘‘I wonder how you teach a child to become a member of a group in a class that small” (p. 38).

Members of the two cultures also had very different interpretations of the probable reasons for Hiroki’s behavior. One American speculated that Hiroki misbehaved because he was intellectually gifted and easily became bored. Not only did the Japanese reject this notion (on the grounds that speed is not the same as intelligence), but they offered a different interpretation. To them, such words as smart and intelligent are almost synonymous with well behaved and praiseworthy, neither of which apply to Hiroki. Hiroki, they believed, had a dependency disorder. Owing to the absence of a mother in the home, he did not know how to be properly dependent and consequently, how to be sensitive to others and obedient. Isolating Hiroki, they reasoned, would not help. Rather, he needed to learn to get along in his group and develop the proper understanding in that context.

Tobin and his colleagues (1989, p. 24) comment on the Japanese view of their preschool system and Hiroki’s behavior as follows:

> *“... Japanese teachers and Japanese society place [great value] on equality and the notion that children’s success and failure and their potential to become successful versus failed adults has more to do with effort and character and thus with what can be learned and taught in school than with raw inborn ability.”*

The Japanese who watched the tape disapproved of the promotion of individualism that they observed in tapes of an American classroom, believing that ‘‘A child’s humanity is realized most fully not so much in his ability to be inde-pendent from the group as his ability to cooperate and feel part of the group” (p. 39). One Japanese school administrator added:

“For my tastes there is something about the American approach [where children are asked to explain their feelings when they misbehave] that is a bit too heavy, too adult like, too severe and controlled for young children (p. 53).”

There are many interesting implications to be drawn from these observations, only a tiny fraction of which are touched on here. However, in the present context my purpose is to relate them to the situation such children will encounter as adults, in particular the situation that Japanese boys will face should they pursue a career in the American pastime of baseball. This point is made in a fascinating account of the fate of American baseball players who play in the Japanese major leagues (Whiting, 1989). Despite their great skill, experience, and physical size, American ballplayers generally have a very difficult time in Japan. There are many reasons for their difficulties, but crucial is a completely different understanding of keys to success in this team sport, a difference that mirrors differences in preschool education in the two cultures to an amazing degree. The title of the book, You Gotta Have WA, pinpoints one key difference. WA is the Japanese word for group harmony, and, according to Whiting, it is what most clearly differentiates Japanese baseball from the American game. Although American ballplayers maintain that individual initiative and innate ability are the key ingredients to success, the Japanese emphasize that ‘‘the individual was nothing without others and that even the most talented people need constant direction” (p. 70). Linked to the emphasis on group harmony is an equivalent emphasis on doryoku, the ability to persevere in the face of adversity as the key to success, whereas Americans emphasized individual talent. Whiting pointed out that the ideals of WA and doryoku are cornerstones not only of Japanese baseball, but of Japanese business as well:

WA is the motto of large multinational corporations, like Hitachi, while Sumimoto, Toshiba, and other leading Japanese firms send junior executives on outdoor retreats, where they meditate and perform spirit-strengthening exercises, wearing only loin-cloths and headband with doryoku emblazoned on them (p. 74).
Despite their acknowledged talent, American players, whose understanding of the sources of success, the cultivation of which can clearly be seen in their preschool education, are generally unable to submit to the Japanese way of doing things. In a remark that echoes poignantly on the Japanese disapproval of the American emphasis on verbalizing and valuing personal feelings over group harmony, one American ballplayer who had a long and acrimonious public dispute with his manager was led to ask in desperation, ‘‘Don’t you think that’s going too far? What about my feelings? I have my pride you know”. To which the manager replied, ‘‘I understand your feelings, however there are more important things”.

Here again we see how culture operating on young children creates an effect conditioned not by present necessity, but by deep beliefs about ''how things work" that serves as a conceptual schema for how they treat children in the present; cultural differences in behavioral organization in the present appear to have relatively minor consequences in the present life of children, but major effects in terms of the long-term organization of their behavior.

5.3. The complementarity of phylogenetic and cultural constraints in acquiring numeracy

In recent decades a good deal of evidence indicates the existence elementary numerical abilities involving small quantities, including counting, addition, and subtraction in both very young human infants and in primates, although there is controversy about the precise processes involved (Boysen and Hallberg, 2000; Gelman and Gallistel, 2004). For example, Gelman and Williams conclude that the pattern of errors evidenced by young infants asked to perform numerical operations on set sizes of three or less objects may indicate the presence of a "common preverbal counting mechanism similar to the one used in animals" (1998, p. 588). Hauser and Carey go somewhat further, concluding that:

> *"Early primate evolution (and probably earlier), and early in the conceptual history of children, several of the building blocks for a representation of number are firmly in place. [These include] criteria for individuation and numerical identity (the sortal object, more specific sortals like cup and carrot, and quantifiers such as one and another). Furthermore, there are conceptual abilities... such as the capacity to construct one to one correspondence and the capacity to represent serial order relations... (1998, p. 82)."*

Studies of numerical reasoning in early childhood indicate that it builds upon these early starting conditions in an orderly fashion. Thus, for example, Zur and Gelman (2004) report that when three year olds who had not attended preschool viewed the addition or subtraction of N objects from a known number and were asked to predict the answer and then check their prediction, they provided reasonable cardinal values as predictions and accurate counting procedures to test their predictions. Such rapid learning in the absence of explicit instruction, they argue, supports the idea that there are "skeletal mental structures that expedite the assimilation and use of domain-relevant knowledge (p. 135)". Data such as these, despite uncertainties about mechanism, support the argument for number reasoning as a core domain, and hence a phylogenetically given human universal.

Evidence from number development in other cultures, however, appears, at least at first glance, to cast doubt on the universality of elementary number reasoning and leaves little doubt that Hatano and Inagaki (2002) are correct in arguing that because innately specified knowledge is still skeletal it is essential to study the ways in which cultural experience interacts with phylogenetic constraints to produce adult forms of numerical reasoning.

To begin with, there are a good many societies in the world that appear to have at most a few count words on the order of “one, two, many” (Gordon, 2004; Pica et al., 2004). While no research has been conducted with infants in such societies using procedures comparable to those used by modularity and core-domain theorists, it is not clear how such an impoverished system could be considered evidence of a universal set of numerical knowledge. Moreover, Gordon (2004) has recently reported that while Pirahã adults living in a remote area of the Amazon jungle display elementary arithmetic abilities for very small arrays, their performance quickly deteriorates with larger numbers. By contrast, Pirahã children who learn Portuguese number words do not display the same limitations as their parents.

This evidence underscores how important cultural influences are for the elaboration of core numerical knowledge. A key factor appears to be the appearance of lexicalized arithmetic knowledge in association with the appearance of cultural practices that arise when economic activities begin to produce sufficient surplus to necessitate record keeping and trade. Saxe, for example, reported that in the late 1970s traditional Oksapmin (New Guinea) arithmetic practices appear to have been at the very beginnings of their capacity to support mathematical reasoning because, according to Saxe (1981), small amounts were traded and one-to-one correspondence often sufficed as a mechanism to mediate exchange. Twenty five years later, owing to greatly increased involvement in trade and intercultural exchange, arithmetic reasoning had become markedly more complex (Saxe and Esmonde, 2005).

When we consider the evidence from two West African societies, both of which engaged in agricultural production, the influence of cultural practices on the development of arithmetic thinking are more pronounced. Jill Posner (1982) compared children from two neighboring groups in the Ivory Coast. The first she characterized as farmers using primitive agricultural methods to seek out a subsistence living; the second also farmed, but in addition engaged in trades such as tailoring and peddling which required frequent participation in the money economy. The children in both groups displayed knowledge of relative quantity, a skeletal principle, but the children from the subsistence farming group displayed far weaker counting skills and calculation skills than those from the group with more

involvement in the money economy, a difference which was compensated for by schooling.

6. From cultural practices to cognitive expertise and changes in brain function

Taken together, each of these lines of research (see Cole, 2006, for additional examples) provides strong support for the complementary roles of phylogenetic and the more refined coordination of experience in cultural practices as jointly required for the development of a variety of cognitive functions. In the final section I seek to bring the story full circle by providing examples of how the cultural organization of experience feeds back on phylogenetically prescribed brain function. Of the increasing variety of such examples becoming available for research (see for example, Baltes et al., 2006) I have chosen two example of cultural practices. The first involves the use of the abacus in contemporary Japan because extant research provides a rich picture of both the way in which cultural practices are organized, their cognitive consequences as measure by standard experimental procedures, and the consequences for brain activity. The second involves the long term behavioral capacities and corresponding brain changes associated with the acquisition of literacy in schools in Portugal.

6.1. The organization and consequences of abacus expertise in Japan

Expertise in abacus operation nicely illustrates how domain-specific cognitive skills develop when a society creates artifacts and cultural practices to support more complex cognitive achievements (Hatano, 1997). An abacus is an external memory and computational device. It can register a number as a configuration of beads, and one can find the answer to a given calculation problem, in principle, by manipulating them. It is no longer used widely in day-to-day commercial activity, but the abacus still constitutes a significant aspect of Japanese culture because it survives as a special artifact, skills for which are valued in circles of enthusiasts. It survives also as an instructional tool: quite a number of children go to private after-school instruction for abacus, and a few of these become enthusiasts. To put it differently, abacus operation is embedded in two kinds of practices, educational and hobby.

People can learn how to operate a (real) abacus in an elementary but serviceable manner in a few hours when they participate in deliberate instruction. Advanced training is geared almost entirely to accelerating the speed of the operations involved. Values respecting the speed of calculation are shared among abacus operators.

As a result of extensive training, abacus operation tends to be gradually interiorized to such a degree that most abacus masters can calculate accurately and even faster

without a physical abacus present than with the instrument itself. During mental calculation, it appears that they can represent an intermediate, resultant number on their ''mental abacus", in the form of a mental image of the configuration of beads, onto which (mentally) they enter, or from which they remove, the next input number. In other words, abacus experts can solve calculation problems by mentally manipulating the mental representation of abacus beads. The interiorization of the operation is an important mechanism for accelerating the speed of calculation, because the mental operation is not constrained by the speed of muscle movement. Thus, expert abacus operators use the real abacus only when they deal with very large numbers that cannot be represented on their mental abacus.

Some abacus operators calculate extraordinarily rapidly (Hatano, 1997). When mixed addition and subtraction problems (e.g., 957 + 709, 143 + 386 + 2095 - 810 - 91,748 + 105...) are presented in print, experts manipulate 5–10 digits per second. Remarkable speed is also observed for multiplication and division. Experts give, for example, an answer for 3 X 3 or 4 X 2 digit multiplication within 5sec. When they use a real abacus, they are basically error-free. Their mental calculation is not entirely free from errors, but their accuracy is quite respectable.

As might be expected, abacus experts' calculations are highly automatic. Experienced abacus operators can converse during calculation, even without the instrument. The conversation cannot be very demanding – usually just a short and simple factual or preferential question–answer exchange is required. However, this feat is remarkable considering that we generally ask people around us to be quiet when we calculate, especially when we do so without paper and pencil.

The case of gaining expertise in abacus operation (both material and mental) exemplifies the socio-cultural nature of expertise (Hatano, 1997). Pupils who attend abacus are usually first sent there by their parents while in elementary school. The parents often believe that the exercise will foster children's diligence and punctiliousness as well as enhance their calculation and estimation ability. Young pupils are motivated to learn abacus skills to get parental praise, especially by passing an exam for qualification. Like many other out-of-school domains of learning in Japan, abacus learning has an elaborated qualification system and frequent exams. It nicely fits with, or even is encouraged by, the fact that Japanese culture emphasizes effort rather than ability (Sato et al., 2004).

The students' motivation changes when they join an abacus club at school or become a representative of the abacus school, in other words, when the operation is embedded in a different kind of practice. Abacus enthusiasts compete in matches and tournaments, as tennis or chess players do. Also like these players, abacus club members not only engage in exercise at least a few hours every day but also seek

knowledge of how to improve their skills. Their learning is strongly supported by the immediate social context of the club and the larger community of abacus operators. Formal and informal relationships with an instructor and peers organize their way of life, and sanctions from other players regulate their daily activities. Moreover, they may participate in the community of abacus operators by taking an administrative role in players' organizations as well as by serving as an examiner or a judge at matches and tournaments. They participate more and more fully by assuming more and more significant responsibilities in the community.

Abacus operators are also socialized in terms of their values, for example, regarding the importance of abacus skills and their status in general education, as well as their respect for the speed of calculation mentioned above. In fact, the community of abacus educators and players constitutes a strong pressure group in the world of education in Japan. In this sense, gaining expertise is far from purely cognitive. It is a social process (Lave and Wenger, 1991), and it involves changes in values and identities (Goodnow, 1990). The experts' values and identities are undoubtedly forms of ''culture in mind", acquired through internalization. They serve as the source of motivation for experts to excel in the target domain.

Expertise in mental abacus operation also induces changes at neural levels. For example, using event-related FMRI, Tanaka et al. (2002) showed that, whereas ordinary people retain series of digits in verbal working memory (revealed as increased activation in the corresponding cortical areas including the Broca's area), mental abacus experts hold them in visuospatial working memory, showing activations in bilateral superior frontal sulcus and superior parietal lobule. Hanakawa et al. (2003) demonstrated, using FMRI, that the posterior superior parietal cortex was significantly more activated while mental additions were performed among mental abacus experts than non-learners of abacus.

6.2. The later consequences of early literacy acquired in school

The detailed results concerning the relation of brain function to culturally organized (abacus)experiments still leaves open the question of what long term morphological changes might be associated with such functional indicators of involvement in cultural practices might also be involved.

There are several sources of such evidence. Perhaps the most intensive study is that of this problem has been carried out by Castro Caldas, Ostrosky, Ardila, their colleagues, and others (see for example, Ardila et al., 1994; Castro Caldas, 2004; Ostrosky et al., 1986). These studies contrast the brain morphology and functions of people who have or have not been to school with those of non-schooled people. Collectively, they have involved a variety of populations ranging from cases in

cultural practices in a Portuguese study where older girls being kept at home while secondborns went to school and were tested decades later, to cross-sectional studies of adults who had experienced varies of levels of education and come from different parts of the same country. Their testing methods were heavily grouped around functions where the impact of cultural practice and plausible brain regions could be identified, e.g. those mediated by print in some fashion. Their brain measures in FMRI, magnetoencephalography (MEG) and PET scans.

Taken individually, various of these studies could be faulted in terms of the extent to which the comparison groups not chosen at random, a problem in all such comparative work (Cole and Means, 1981). Taken as an ensemble, they lead Castro Caldas to conclude that it is possible to identify brain structures that can be identified with the functions of reading and writing, both from the functional and from the anatomical points of view:

> *"Results concerning visual processing, cross-modal operations (audiovisual and visuotactile), and interhemispheric crossing of information are reported. Studies with magnetoencephalography, with positron emission tomography, and with functional magnetic resonance provided evidence that the absence of school attendance at the usual age constitutes a handicap for the development of certain biological processes that serve behavioral functioning. Differences between groups of literate and illiterate subjects were found in several areas: while dealing with phonology a complex pattern of brain activation was only present in literate subjects; the corpus callosum in the segment where the parietal lobe fibres cross was thinner in the illiterate group; the parietal lobe processing of both hemispheres was different between groups; and the occipital lobe processed information more slowly in cases that learned to read as adults compared to those that learned at the usual age (2004, p. 7)."*

7. Conclusion

These findings with respect to linkages between practices and brain changes fit with the findings of Scribner, Cole, and their colleagues based entirely on a combination of psychological and ethnographic methods among the Vai. Their research, which included people who become literate without schooling, as well as those who attend school to become literate. They concluded that the consequences of literacy are cultural-function and context-specific. They become generally on in so far as they are taken up as constituents of many practices. This is precisely the conclusions to which the research concerning stabilized images led us at the beginning of this chapter.

Culture and phylogeny have, as Geertz asserted, been wound together in the process of hominization ‘‘since the beginning”. History, in this sense, can become destiny. But only in so far as the non-linear causal weight of culture fails to provide sufficient constraints to demand brain specialization; the co-constitution of culture and biology can no longer be ignored in studies of human learning and development. The degree of their generality varies directly with the A group of 64 illiterate normal subjects was selected in the Mexican Republic. Their performance was compared with two barely schooled control groups (1–2 and 3–4 years of schooling). The subjects’ ages ranged from 16 to 85 years. In the second analysis, the illiterate subjects were further matched by age and sex with individuals with 1–4, 5–9, and 10–19 years of formal education. The Spanish version of the NEUROPSI neuropsychological test battery (Ostrosky et al., 1998) was used. Results indicated a significant educational effect on most of the tests. Largest educational effect was noted in constructional abilities (copying of a figure), language (comprehension), phonological verbal fluency, and conceptual functions (similarities, calculation abilities, and sequences). Aging effect was noted in visuoperceptual (visual detection) and memory scores. In the first subject sample, it was evident that, despite using such limited educational range (from 0 to 4 years of formal education), and such a wide age range (from 16 to 85 years), schooling represented a stronger variable than age. It is proposed that education effect on neuropsychological test performance represents a negatively accelerated curve, tending to a plateau.

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